AD-A011 346

THE BIOLOGICAL CONTROL OF ALLIGATORWEED

Neal R. Spencer, et al

Agricultural Research Service
Gainesville, Florida

March 1975

For: Proceedings, Univ. of Fla.
EPA Conference on
Biological Control of
Aquatic Macrophytes

Send Galley Proof To:
N. R. Spencer
Biological Control Lab.
P. O. Box 1269
SR - ARS - USDA
Gainesville, FL 32602

THE BIOLOGICAL CONTROL OF ALLIGATORWEED

Neal R. Spencer
Research Leader
Biological Control Lab.
SR - ARS - USDA
Gainesville, Florida

and

Jack R. Coulson
Chief
Beneficial Insect Introduction Lab.
IIBIII, Beltsville Agric. Res. Center
NER - ARS - USDA
Beltsville, Maryland

March 1975

THE BIOLOGICAL CONTROL OF ALLIGATORWEED

N. R. Spencer & J. R. Coulson

The Plant

Alligatorweed, Alternanthera philoxeroides (Mart.) Griseb., an aquatic amaranth introduced into the United States from South America around the turn of the century, has become a noxious aquatic weed over the past 40 years. ~~(Fig. 1)~~. After ~~its~~ introduction the plant spread rapidly in the United States, infesting aquatic and wetland areas from North Carolina southward to Florida and westward through Alabama, Mississippi, and Arkansas to Texas. In South America, alligatorweed is established from southern Argentina to Central America.

Alligatorweed is not known to produce viable seed in the United States. Reproduction is vegetative, each node being capable of producing a complete plant. Mechanical destruction of the mats without removal of all plant material results in proliferation of the weed. The weed may be rooted in moist soil, along the banks of bodies of water, or in shallow water areas. In water more than 60 cm in depth, alligatorweed may form a floating mat of interwoven stems. The internode space in this situation is hollow and capable of buoying the emergent, photosynthetic portion of the plant; roots from the nodes obtain nutrients from the water. Large densely woven mats impede water movement, restrict traffic on navigable waterways, and restrict fishing and recreational uses of lakes, streams, and rivers. Damage to agriculture is incurred as alligatorweed blocks drainage and irrigation channels, thus increasing the threat of flooding during periods of high water. In addition, the weed causes public health problems by increasing mosquito breeding areas and by water pollution from plant decomposition.

The Problem

Alligatorweed has been classed as a weed because of its competitive advantage over native vegetation and development of these extensive interwoven mats of plant material that may extend three feet or more down into the water and hundreds of feet over the surface (Fig. 2). This development of dense plant material results in the perennial alligatorweed choking out native vegetation and forming a monotypic community. Waterhyacinth appears to be one of the few plants capable of competing with alligatorweed for space and nutrients in an aquatic environment. We have seen sprigs of alligatorweed growing among waterhyacinth plants which were compacted in a cove. A borrow canal in Louisiana may have a continuous waterhyacinth mat then abruptly change to an adjacent alligatorweed mat. If alligatorweed occupies an area of water, waterhyacinth cannot invade that space unless the alligatorweed mat is damaged or moved by wind or wave action. Much the same is true if waterhyacinth is the original invader.

Alligatorweed was recognized as a threat as early as 1901, but its potential as a serious aquatic weed problem was not fully recognized until the use of herbicides in 1945. The use of these herbicides for waterhyacinth control resulted in a corresponding increase in alligatorweed. Alligatorweed is less susceptible to the action of herbicides and therefore gained a competitive advantage. By 1963 surveys showed that alligatorweed infested an estimated 162,400 acres of water in North and South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas (U. S. Army Corps of Engineers, 1965). Smaller infestations are known to occur in Virginia, Arkansas, Tennessee, and California (Massey, 1955; Weldon, 1960).

In addition, alligatorweed has been introduced to Asia, Australia, and Africa (Sculthorpe, 1967).

Controls

The need for controlling these introduced aquatic weeds, such as waterhyacinth, was recognized as early as 1899, when Congress authorized the U. S. Army Corps of Engineers to begin operations to remove waterhyacinth from navigable waters in Florida and Louisiana. In 1945, after the advent of herbicides, chiefly 2,4-D, in aquatic weed control programs, the U. S. Army Corps of Engineers was asked by Congress to determine the feasibility, nature, and potential benefits of an expansion of their aquatic weed control activities. This resulted, in 1958, in an "Expanded Project for Aquatic Plant Control", for which Congress authorized the Corps of Engineers to make a detailed study of the control and eradication of aquatic weeds from waterways in the Gulf and South Atlantic Coastal States (U. S. Army Corps of Engineers, 1965). In addition to their own research and control efforts, the Corps of Engineers has supported research on better methods of chemical and mechanical control of waterhyacinth and alligatorweed, and on studies of the biologies of the weeds. Research on practical uses of the plants has also been conducted. Beginning in 1959, an increasing portion of this support was devoted to research on the possibilities of biological control of aquatic weeds. This latter research, completely supported by funds from the Corps, has been performed by personnel of the Agricultural Research Service (ARS) of the U. S. Department of Agriculture.

Exploration for Natural Enemies

In 1960 and 1961, explorations were made in South America by George B. Vogt, an ARS entomologist of the Systematic Entomology Laboratory, Washington, D. C., to search for natural enemies of alligatorweed in its native habitats. In 1961, an ARS-supported Special Foreign Currency (PL-480) project was initiated with Ing. A. Silveira Guido in Uruguay to study natural enemies of aquatic plants. And in 1962, an ARS laboratory was established in Argentina to study further the more promising arthropods found during the earlier surveys and the PL-480 research (Anderson, 1965). The research in Argentina was conducted by Donald M. Maddox from 1962-1967, B. David Perkins, 1968-1971, and C. J. DeLoach, 1971 to July 1, 1974.

A decision was made to concentrate the early research efforts on the potential biological control of alligatorweed because this weed was more difficult to control by herbicides than was waterhyacinth (J. R. Coulson, in manuscript).

An excellent account of the early exploratory work and the later experimental studies on alligatorweed and its natural enemies in South America is given by Maddox, et al. (1971), and in the reports by Vogt (1960, 1961) and Silveira Guido (1962, 1963), Maddox (1968), and Maddox and Resnik (1968, 1969).

Limited field studies of alligatorweed infestations in California and in the southeastern United States were conducted by Maddox during 1961-1962, and later by other members of the USDA - ARS Biological Control of Weeds Research Laboratory, Albany, California, under the direction of Dr. Lloyd A. Andres. From 1965 to 1969, additional research on native

North American natural enemies of introduced aquatic weeds, including alligatorweed and waterhyacinth, was conducted in Louisiana under the direction of A. D. Oliver, Department of Entomology, Louisiana State University, under an ARS-supported research grant. In addition, Vogt has conducted considerable field investigation on alligatorweed and its natural enemies in the United States, the results of which are soon to be published (G. B. Vogt, personal communication).

In 1970 an ARS research unit was established in Gainesville, Florida, to intensify research on biological control of aquatic weeds. The principal emphasis of the Gainesville laboratory from 1970 through 1972 was on increasing the effectiveness of the insects introduced earlier for the control of alligatorweed, and the introduction and establishment of *Vogtia malloi* Pastrana (Lepidoptera: Pyralidae: Phycitinae) (Brown and Spencer, 1973; Foret, et al., 1974; Spencer, 1974). From 1972 to date, emphasis at the Gainesville laboratory has shifted slowly from alligatorweed to waterhyacinth.

During the South American explorations, over 40 arthropod species were found associated with alligatorweed. Vogt classified the majority of these as "minor biotic suppressants", considering only five of the insect species found as important natural control factors for alligatorweed (Vogt, 1960, 1961; Maddox, et al., 1971). Of these five insects, only three appeared suitable for introduction into the United States as biological control agents of alligatorweed. These insects, all three of which were undescribed at the time of their discovery, have since been named and described; they are: 1) *Agasicles hygrophila* Selman and Vogt (Coleoptera: Chrysomelidae), now commonly known as the "alligatorweed flea beetle"; 2) Amynothrips andersoni O'Neill (Thysanoptera: Phlaeothripidae), the "alligatorweed thrips"; and 3) V. malloi, the so-called "alligatorweed stem-borer". A general discussion of the biology, feeding behavior, and resulting plant damage of these insects is given by Maddox, et al. (1971).

As a result of the necessary, long-term laboratory studies, which were conducted at the ARS laboratories in Argentina and at Albany, California, the host specificity of these insects was assured. Clearance for their release in the United States was obtained from the Federal Working Group on Biological Control of Weeds, and the U. S. Department of Agriculture's regulatory agency (now the Plant Protection and Quarantine Programs, Animal and Plant Health Inspection Service), and from authorities in the various states in which releases were intended. (For a description of the procedures involved in obtaining clearance for the introduction of foreign weed-feeding insects into the United States see Zwölfer, H. and P. Harris, 1971; and Coulson, J. R., 1974.) Agasicles was first released in the United States in 1964, Amynothrips in 1967, and Vogtia in 1971 (Brown and Spencer, 1973). All three species have since become established in certain areas of the southeastern United States.

Agasicles hygrophila Selman and Vogt

The alligatorweed flea beetle (Fig. 4), commonly called Agasicles by those who have worked closely with it, was the first biocontrol agent studied. It was described by Selman and Vogt (1971). Approval for the importation of Agasicles into the United States was recommended by the Federal Working Group on the Biological Control of Weeds in August 1963, and permits for its importation were issued by the USDA in January 1964.

Although Agasicles became established in the Savannah National Wildlife Refuge, South Carolina during 1964, the first successful release and establishment of Agasicles population was made in a dense mat of alligatorweed on the Ortega River in Jacksonville, Florida in April 1965 (Zeiger, 1967; Hawkes, et al., 1967). In an acceptable environment, an Agasicles female may lay 1,000 eggs, and a complete generation may take no more than 25 days at 22°C (Maddox, 1968). By June of 1966, the floating mats at the release site were dead and disintegrating, and only a fringe of heavily damaged alligatorweed remained along the banks; the weed has never recovered at this site.

Most of the alligatorweed flea beetles that have become established in the United States are the progeny of the beetles released on the Ortega River. These Agasicles originated from the Ezeiza Lagoon area near Buenos Aires, Argentina. Coulson (in manuscript) gives details of the releases of Agasicles in the United States. Over 7,700 beetles in the spring of 1966 and another 1,500 in the fall of the same year were collected from the Ortega River site for release in other sites in Florida, Georgia, South Carolina, and Mississippi.

Natural dispersion of the alligatorweed flea beetle occurred rapidly at release sites as the beetles destroyed the alligatorweed. In August of 1967 this ability to disperse resulted in beetles being found as far north as Waycross, Georgia and at another site some 75 miles northwest of the Ortega River release site.

Although Louisiana was ranked first in amount of alligatorweed, it was the last to receive introductions of Agasicles. This was due to some conflicts of interest and misunderstandings. Cattlemen in southern Louisiana sometimes feed their cattle on terrestrial and semi-terrestrial alligatorweed during periods when other forage is unavailable. Also, pelts of the fur-bearing nutria are sought by trappers in Louisiana and these animals sometimes use alligatorweed as food. Alligatorweed is also a deer browse and is sometimes used in crayfish culture.

A public hearing was held at Lake Charles, Louisiana, on July 29, 1970, on the possible use of biocontrol agents for alligatorweed control. As a result of discussions at this meeting it was learned that the concern in Louisiana was primarily for terrestrial and semi-terrestrial alligatorweed and that there was an interest in reducing the alligatorweed in aquatic habitats. Because experience with Agasicles had shown that it prefers, and almost restricts itself, to aquatic alligatorweed, it was generally agreed that the release of Agasicles in Louisiana would have benefits outweighing any detrimental effects. No further objections were received following this hearing, and clearance for release of Agasicles in Louisiana was granted in December 1970.

Two factors are important to the ability of Agasicles to establish and flourish on its host, alligatorweed. Number one is temperature; the beetle is poorly adapted to freezing winters because of a lack of a diapause. If all alligatorweed is frozen back to the water line, the flea beetles will starve during the winter. Agasicles is also poorly adapted to temperatures above 26°C. Maddox (in litt.) found that the fecundity of Agasicles is reduced as the temperature goes above 26°C. This effect of temperature has been noted in the field where poor population buildup is seen in south Florida and other areas with long, warm summers.

In the northern portion of its range, *Agasicles* may build up from a small overwintering population to a single population peak in the fall. Where a higher number of beetles survive the winter in areas from 28° to 32° N lat. two population peaks occur, one in the spring and a second in the fall. This split peak is due to the summer decline in the *Agasicles* population that is associated with higher summer temperatures.

The second factor important to the ability of an *Agasicles* population to flourish is the quality of the alligatorweed. We have noted, at alligatorweed sites in the southeast, that the beetles were rarely evident where alligatorweed had showed symptoms of low nutrient availability. The symptoms included internode diameter and length, plant height, stem density, and leaf area. Brown (1973) found positive statistical correlations in the number of *Agasicles* and *Vogtia* at a site and the plant characteristics named above.

Amynothrips andersoni O'Neill

Information on this thrips may be found in papers by Maddox, et al. (1971), Maddox and Mayfield (1972), Maddox and Resnik (1968), Vogt (1960, 1961), and Maddox (1973). The species was not described until 1968 (O'Neill, 1968).

Approval for the importation of the alligatorweed thrips into the United States was obtained from the Federal Working Group on the Biological Control of Weeds in May 1966. Permits were granted by USDA later that year. Thrips were imported from Argentina in the latter part of 1966 and a colony was established at the USDA Biological Control of Weeds Laboratory in Albany, California.

Releases, after the necessary state clearances, were made in Florida, Georgia, South Carolina, and California in 1967. *Amynothrips* was first released in Mississippi and Texas in 1968 and in Alabama in 1969.

Amynothrips populations are known to be established only in areas of South Carolina, Florida, and Georgia. Detailed field investigations have not been conducted at most of the release sites, and the thrips may well be established at other sites. Populations of the thrips were found in 1970 on the Ashepoo River near Jacksonboro, South Carolina, a distance of nearly 10 miles from the 1967 release site on the Edisto River (W. C. Durden, personal communication). Established populations of the thrips exist at the Savannah National Wildlife Refuge just across the Georgia State line in South Carolina and on the Ortega River in Jacksonville, Florida. In general, however, populations of *Amynothrips* capable of effectively controlling alligatorweed have not developed.

Two factors may have apparently accounted for the lack of *Amynothrips* to build up populations in the United States. We believe that pressure is exerted on the thrips by predators, chiefly flower bugs in the genus *Orius* (Anthocoridae). This predator pressure prevents the thrips from building up high populations over short periods of time. There is the possibility, however, that once the *Amynothrips* population in a release area develops past a density that *Orius* is capable of handling, predation will no longer be an important factor governing the thrips population.

The second factor that affects the ability of *Amynothrips* to reproduce and multiply on alligatorweed in the United States is flight. O'Neill (in litt.) doubts that *Amynothrips* is capable of flight. O'Neill is not convinced that even the fully macropterous individuals of this species can fly. This inability to fly would, of course, restrict their rate of dispersion.

In 1974 a spread of Amynothrips was noted on the Ortega River near Jacksonville, Florida. The thrips was found several hundred yards from the original release site. All of the rooted alligatorweed in a small cove, left after the attacks by Agasicles and Vogtia, was infested with the thrips. The terminal growth showed the characteristic distortion common to this insect (Fig. 5). The plants appeared stunted due to the combination of insect damage and low nutrient levels. It appears that alligatorweed will continue to occupy a portion of the site on the Ortega River, but its growth will be severely limited by biotic stress. In this area alligatorweed can no longer be classed as a weed species. It is an acceptable member of the aquatic plant community.

Maddox, et al. (1971) estimated that Amynothrips went through 4 generations a year in South America. The thrips may slowly develop populations large enough to escape some of the predation pressure it is now under in the United States. We believe that we are beginning to see this result on the Ortega River. As Amynothrips populations build up in the United States they should spread, though perhaps slowly, and eventually have greater impact on alligatorweed.

Vogtia malloi Pastrana

Vogtia malloi, the alligatorweed stem borer (Fig. 6), was described in 1961 by Pastrana (1961). Vogt (1960) found the moth, together with the thrips, to be the most geographically widespread of all alligatorweed natural enemies in South America. In his studies of Vogtia, Vogt believed the moth to have a far greater average flight range and total range than any of the other host specific insects found on alligatorweed. The moth was found from southern Argentina to northern Venezuela.

Approval for the release of Vogtia in the United States was obtained from the Federal Working Group in December 1970, and state approvals were obtained for release in Florida, Georgia, South Carolina, and North Carolina in 1971 and Alabama in 1972. Three shipments, totaling 223 larvae and 23 pupae, collected from alligatorweed-infested ditches at Bella Vista near Buenos Aires, were sent to the Albany laboratory from February 23 to April 14, 1971. A total of 4078 eggs obtained from moths reared from these larvae were sent from Albany to the Gainesville, Florida, laboratory in six shipments from April 3 to July 16, 1971, and 813 eggs were sent to Georgia on April 12 for field release. Some of the eggs received at Gainesville were used to establish a culture of Vogtia in the greenhouse, and the remainder were released in Florida. Additional releases in Florida, in North and South Carolina, and in Georgia were made in 1971 from material obtained from the successful greenhouse culture at Gainesville. Initial results of these releases are discussed by Brown and Spencer (1973). Establishment was apparently effected only at the Lake Lawne, Lake Alice, and Black Lake sites in Florida, and overwintering occurred at the USDA station at Savannah, Georgia.

The first release site was in an alligatorweed infested stream on the campus of the University of Florida at Gainesville, in May of 1971. The population increased and dispersed randomly from the release site, reducing the aerial alligatorweed stems from 52.5 to 4.0 per square foot in 4 generations. In 1972 Vogtia populations again built up at this site. The number of insect larvae and of aerial stems of alligatorweed were measured from the spring through November when the population of both insects and plants approached that of the year before (Table I). Alligatorweed at this site has since declined to the point that only occasional aerial stems were seen in the water in mid-1974. This damage is in part due to the ability of a single larva to damage as many as nine stems during the course of its development (Maddox, et al., 1971).

In 1971 and 1972 Vogtia was released along the Atlantic seaboard and in the peninsular part of Florida. In the spring of 1974 the moth was found in southern Louisiana attacking 1-4% of the alligatorweed stems measured. By the fall of that year Vogtia had built up to damaging populations in Louisiana, Arkansas, and Mississippi, and had also been found in Texas by G. B. Vogt and P. C. Quimby, Jr., ARS, Stoneville, Mississippi (personal communication).

Spencer has found Vogtia in the Santee-Cooper Reservoir area in South Carolina where it inflicted heavy damage on alligatorweed. The extreme decline of alligatorweed on the reservoir in 1973 and 1974 can be traced to the overwintering ability of Vogtia in an area of 30+ days below 0°C each year. Vogtia promises to be the most widespread of the introduced enemies in the United States.

Conclusion

With the establishment of Agasicles on the Ortega River and its rapid spread in the Southeast in the latter part of the 1960's and into the 1970's, it was apparent that a substantial amount of alligatorweed in the Southeastern United States was being controlled biologically. The control, however, was erratic and limited to areas without extreme winter or summer temperatures. Even with these drawbacks Agasicles was considered an important introduction and the basis for a very successful biological control program.

Vogtia malloi was the last of the three insects to be introduced. With this introduction we went from a moderately successful control program that tended to be limited to a portion of the range of alligatorweed to a substantial control of alligatorweed over the entire range where it occurred as an aquatic plant problem.

It is our contention that alligatorweed will cease to be an important aquatic weed and only rarely will be found in pure stands in any significant proportions. In other words, the stress now being placed upon the plant by the introduction of the three species of insects will cause it to become an acceptable member of the aquatic plant community in the United States.

Acknowledgements

The biological control of alligatorweed in the United States is the result of a research effort made by entomologists of the Agricultural Research Service of the U. S. Department of Agriculture. This work was supported by the U. S. Army Corps of Engineers. Figures 2 and 3 are U. S. Army photographs and were made available through the courtesy of A. P. Cannon, Forester, Fort Stewart, Georgia. Figures 4, 5, and 6 were furnished by R. C. Bjork, ARS Information Office, Washington, D. C.

REFERENCES CITED

Anderson, W. H. 1965. Search for insects in South America that feed on aquatic weeds. Proc. South. Weed Conf. 18: 586-87.

Brown, J. L. 1973. Vogtia malloi, a newly introduced pyralid (Lepidoptera) for the control of alligatorweed in the United States. PhD Thesis, University of Florida, Gainesville, Florida. 71 pp.

_____, and N. R. Spencer. 1973. Vogtia malloi, a newly introduced phycitine moth (Lepidoptera: Pyralidae) to control alligatorweed. Environ. Entomol. 2: 519-23.

Coulson, J. R. 1974. Potential environmental effects of the introduction of the Argentine water hyacinth weevil, Neochetina eichhorniae, into the United States. Aquatic Plant Control Program, Tech. Report 6, U. S. Army Corps of Eng., WES, Vicksburg, Mississippi.

_____. 1975. Biological control of alligatorweed, 1959-1972, a progress report and evaluation. (In manuscript)

Foret, J. A., N. R. Spencer, and E. O. Gangstad. 1974. Towards integrated control of alligator weed. In Aquatic Plant Control Program, Tech. Report 7, U. S. Army Corps of Eng., WES, Vicksburg, Mississippi.

Hawkes, R. B., L. A. Andres, and W. H. Anderson. 1967. Release and progress of an introduced flea beetle, Agasicles n. sp., to control alligatorweed. Jour. Econ. Entomol. 60: 1476-77.

Maddox, D. M. 1968. Bionomics of an alligatorweed flea beetle, Agasicles sp., in Argentina. Ann. Entomol. Soc. Amer. 61: 1299-1305.

_____. 1973. Amynothrips andersoni (Thysanoptera: Phlaeothripidae), a thrips for the biological control of alligatorweed. 1. Host specificity studies. Environ. Entomol. 2: 30-37.

_____, L. A. Andres, R. D. Hennessey, R. D. Blackburn, and N. R. Spencer. 1971. Insects to control alligatorweed, an invader of aquatic ecosystems in the United States. BioScience 21: 985-91.

_____, and A. Mayfield. 1972. A method of rearing and studying Amynothrips andersoni in the laboratory. Jour. Econ. Entomol. 65: 1521-23.

_____, and M. E. Resnik. 1968. Radioisotopes--a potential means of evaluating the host specificity of phytophagous insects. Jour. Econ. Entomol. 61: 1499-1502.

_________. 1969. Determination of host specificity of the alligatorweed flea beetle, Agasicles n. sp., with radioisotopes. Jour. Econ. Entomol. 62: 996-99.

Massey, A. B. 1955. Alternanthera in Virginia. Va. Jour. Sci. 6: 249.

O'Neill, K. 1968. Amynothrips andersoni, a new genus and species injurious to alligatorweed. Proc. Entomol. Soc. Wash. 70: 175-83.

Pastrana, J. A. 1961. Una nueva Phycitidae (Lep.) parasito de la lagunilla. Tech. Pub. 71, Secretaria de Estado de Agricultura y Ganaderia de la Nacion, Instituto Nacional de Tecnologia Agropecuaria, Instituto de Patologia Vegetal (Argentina).

Sculthorpe, C. D. 1967. The Biology of Aquatic Vascular Plants. Edward Arnold (Publishers) Ltd. London, 610 pp.

Selman, B. J., and G. B. Vogt. 1971. Lectotype designations in the South American genus Agasicles (Coleoptera: Chrysomelidae), with description of a new species important as a suppressant of alligatorweed. Ann. Entomol. Soc. Am. 64: 1016-20.

Silveira Guido, A. 1962 (unpublished). Natural enemies of aquatic plants. First Annual Report. Univ. de la Republic, Facul. de Agron., Dept. de Sanidad Vegetal [Rpt. of PL-480 Project S9-CR-1, Oct. 1, 1962 - Sept. 30, 1963], 55 pp.

_____. 1963 (unpublished). Natural enemies of weed plants. Second Annual Report. Univ. de la Republic, Facul. de Agron., Dept. de Sanidad Vegetal [Rpt. of PL-480 Project S9-CR-1, Oct. 1, 1962 - Sept. 30, 1963], 55 pp.

Spencer, N. R. 1974. Insect enemies of aquatic weeds. PANS 20: 444-50.

U. S. Army Corps of Engineers. 1965. Expanded Project for Aquatic Plant Control. U. S. House of Representatives, 89th Congress, 1st Session, House Document No. 251, 148 pp.

Vogt, G. B. 1960 (unpublished). Exploration for natural enemies of alligatorweed and related plants in South America. U. S. Dept. Agr., ARS, Entomol. Res. Div., Insect Identification and Parasite Introduction Res. Branch, Spec. Rpt. PI-4, 58 pp.

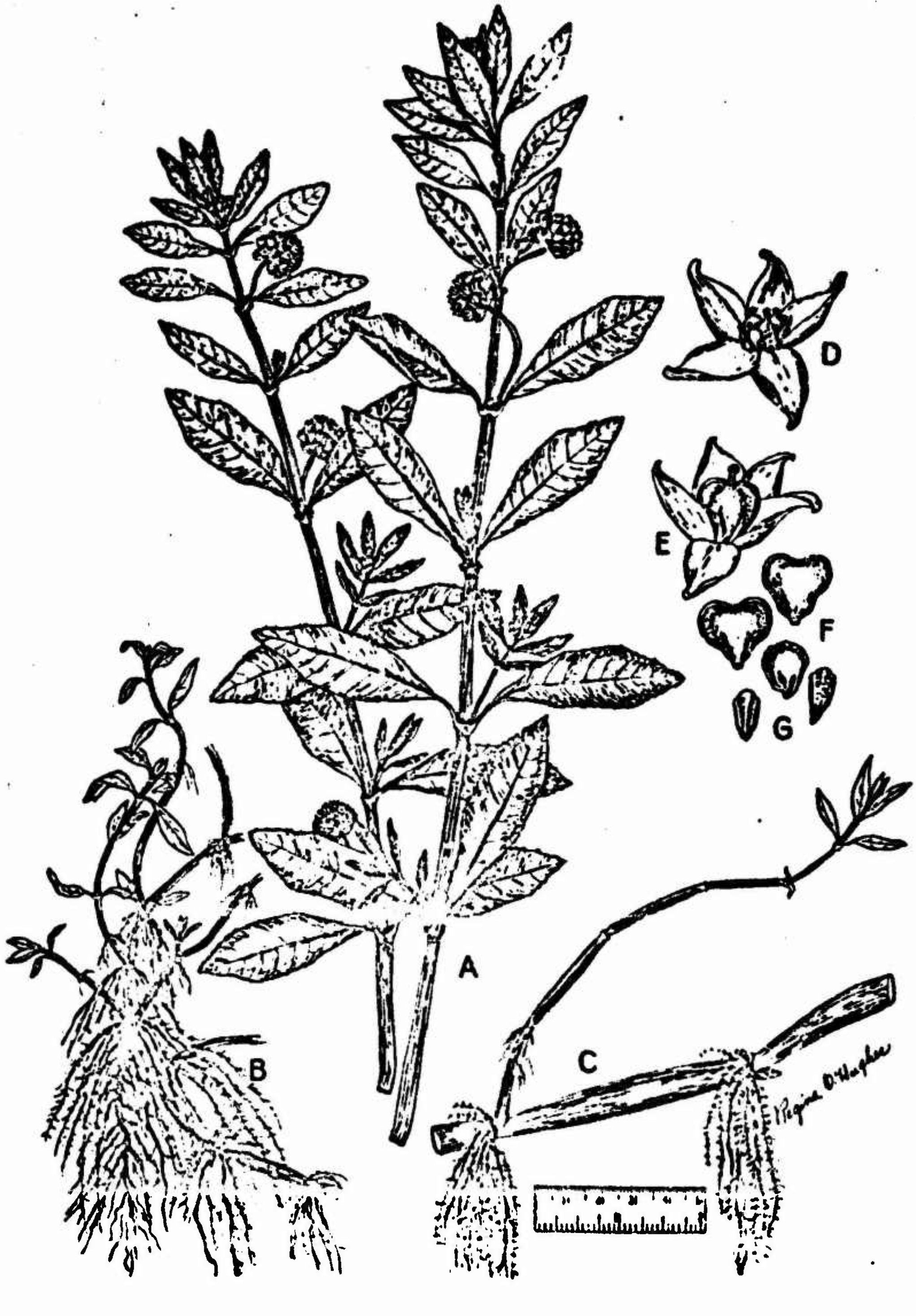
_____. 1961. Exploration for natural enemies of alligator weed and related plants in South America. U. S. Dept. Agr., ARS, Entomol. Res. Div., Insect Identification and Parasite Introduction Res. Branch, Spec. Rpt. PI-5, 50 pp. [Published as Appendix B, 66 pp. In Gangstad, Scott, and Cason (1973)]

Weldon, L. W. 1960. A summary review of investigations on alligatorweed and its control. U. S. Dept. Agr., ARS, Crops Res. Div. Series CR 33-60, 41 pp.

Zeiger, C. F. 1967. Biological control of alligatorweed with Agasicles n. sp. in Florida. Hyacinth Control Jour. 6: 31-34.

Zwölfer, H., and P. Harris. 1971. Host specificity determination of insects for biological control of weeds. Ann. Rev. Entomol. 16: 159-78.

LIST OF FIGURES


D
E
F
G
A
B
C

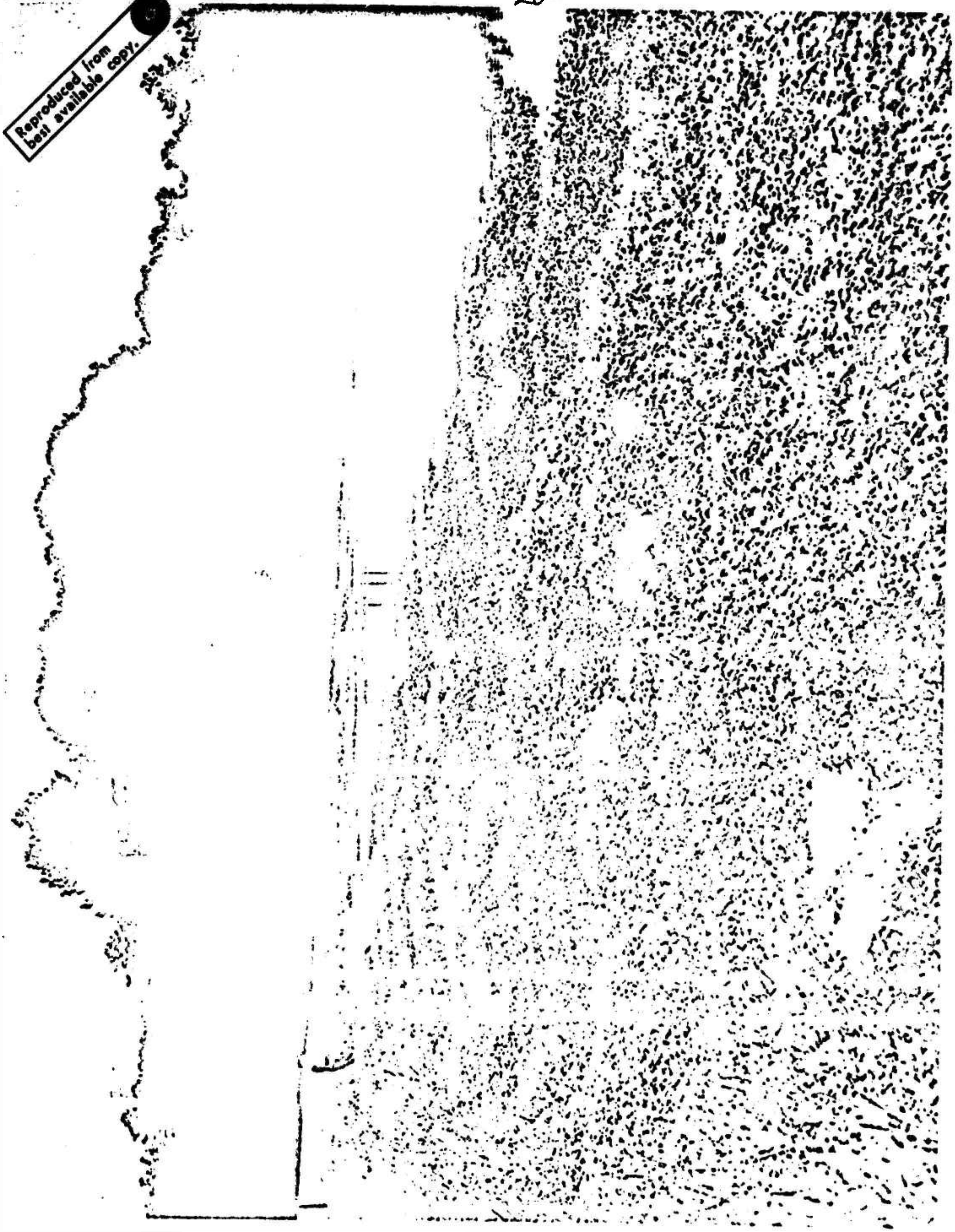


FIG. 2

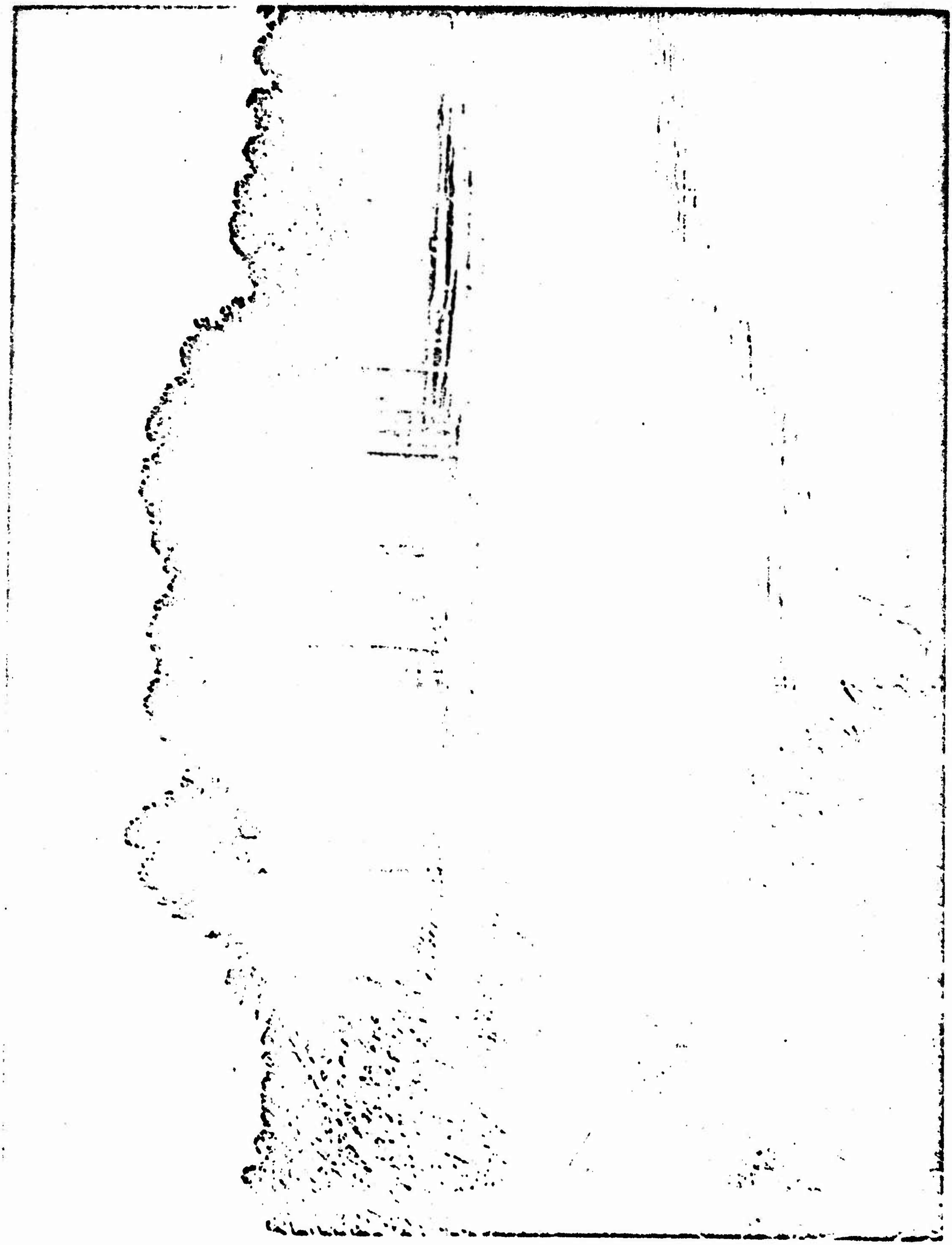
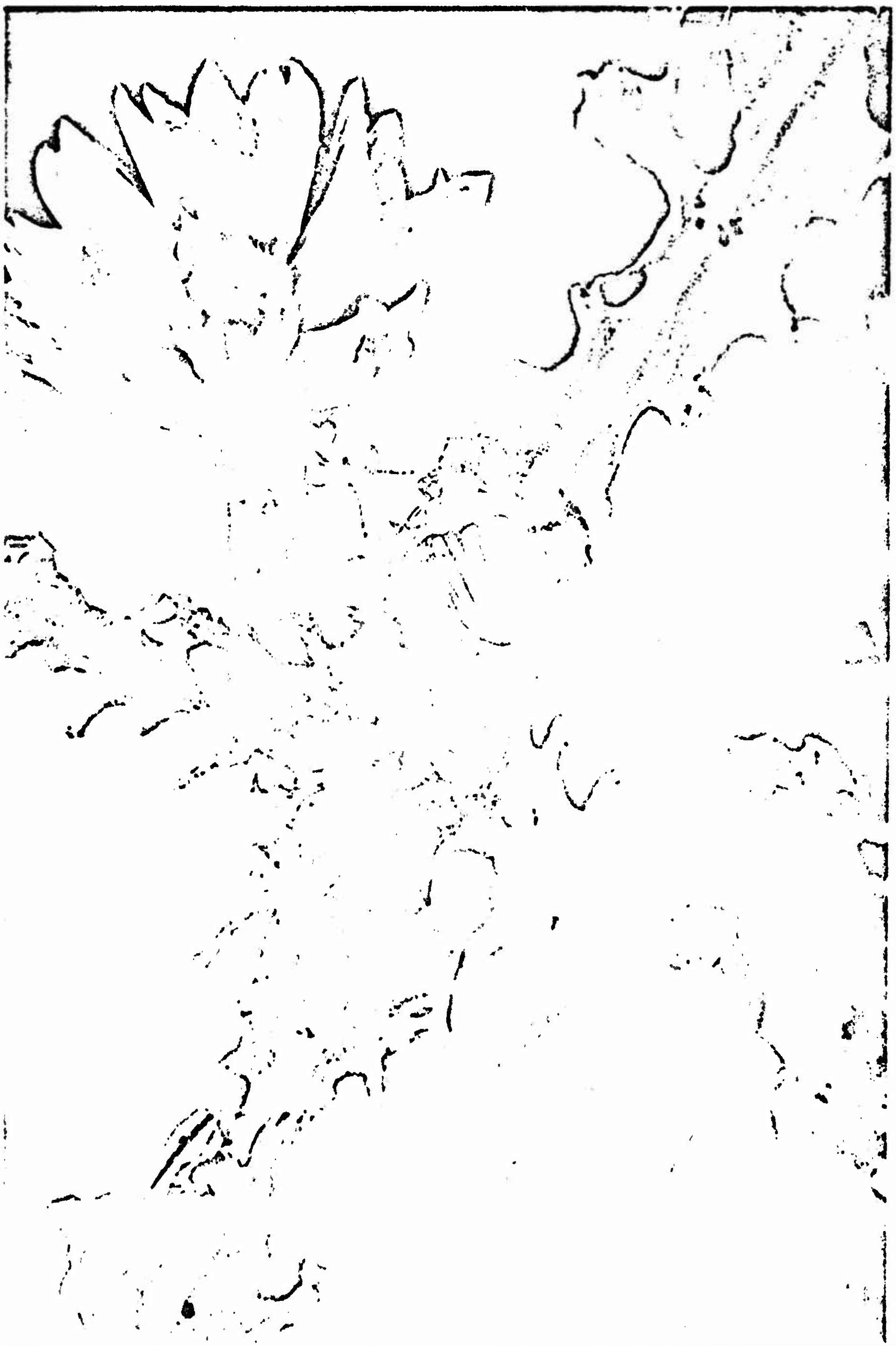
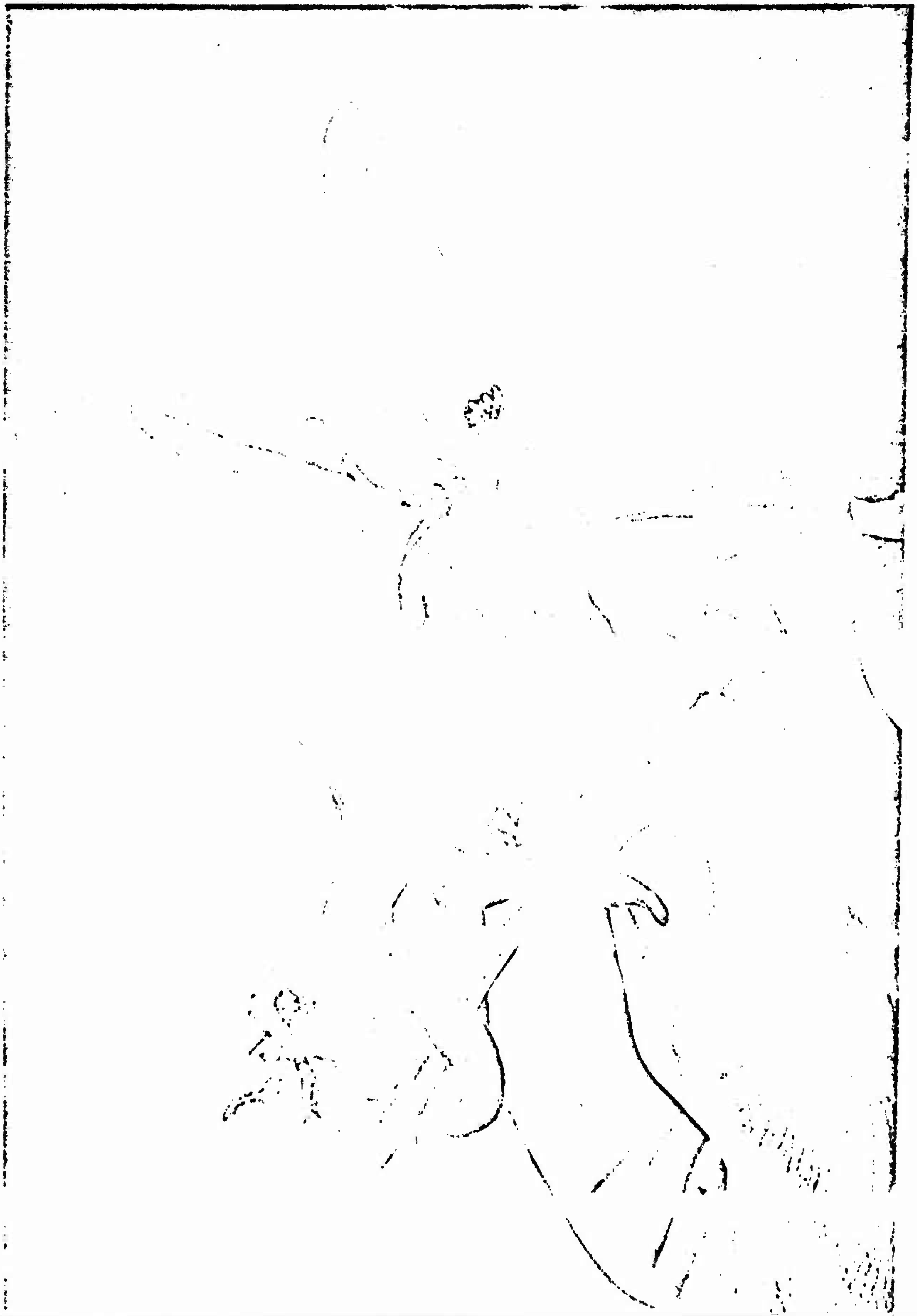


FIG. 3





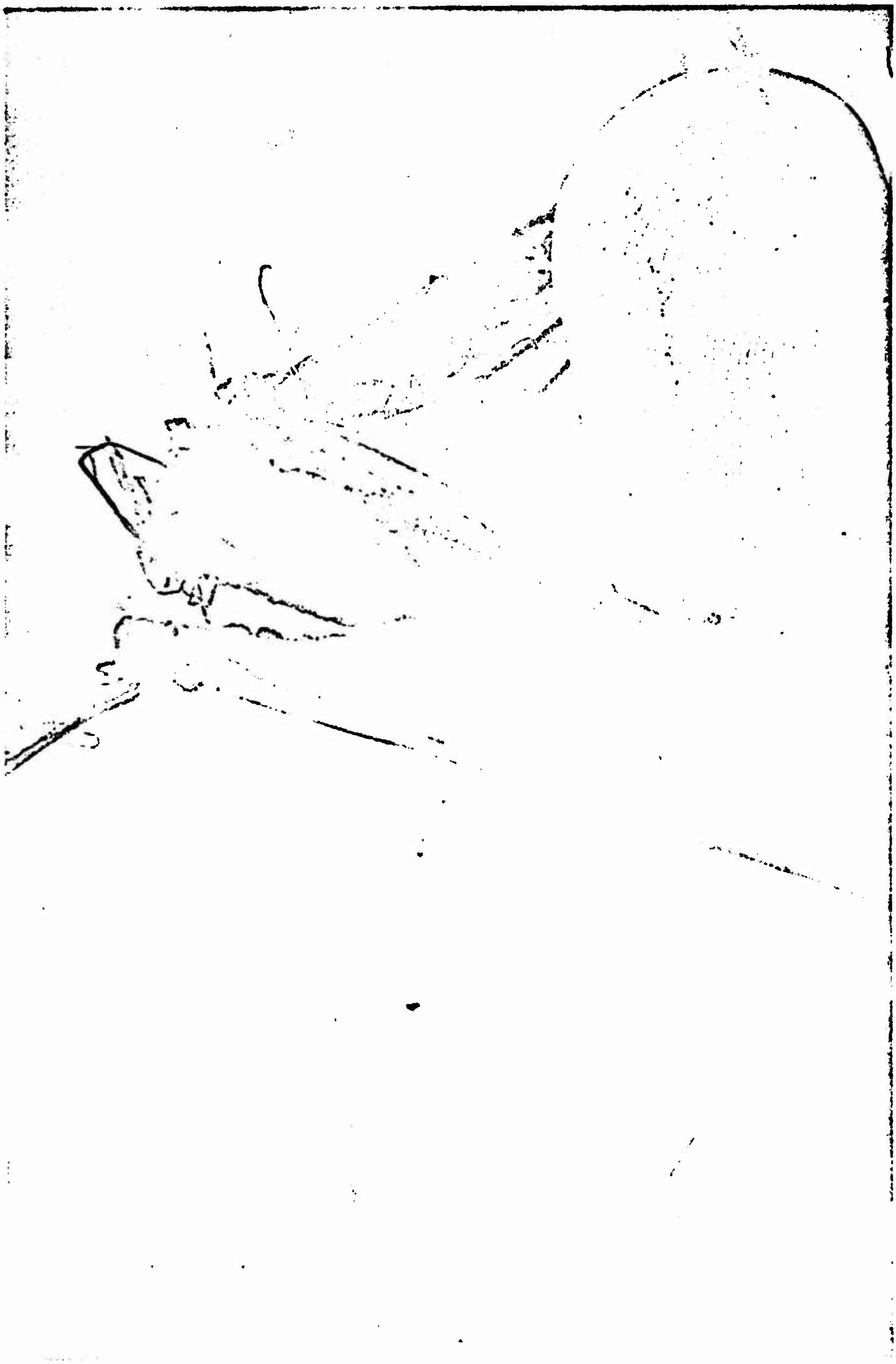


TABLE I. VOGTIA POPULATION BUILDUP AND ITS EFFECT ON ALLIGATORWEED, LAKE ALICE. U. of FLA. GAINESVILLE, FL.